

USING CONSEQUENTIAL LCA AND OPTIMIZATION TO IDENTIFY THE BEST USES OF BIOMASS RESOURCES WITHIN THE ENERGY SECTOR

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In the attempt to mitigate global temperature increase, a strong focus is placed on reducing the greenhouse gas (GHG) emissions from the energy sector, accounting for ca. 65% of the global GHG emissions (Herzog, 2009). Focusing on the Danish energy system as a case study, this study used consequential life-cycle assessment (LCA) and mathematical optimization to highlight optimal uses of the domestic (and eventual imported) biomass resources. This was done by: i) quantifying potentials and characterizing compositions of available biomass, ii) developing consequential LCA scenarios for energy conversion of each individual biomass (including co-products and possible induced effects, e.g. Land-Use Changes LUC) using an *ad hoc* biochemical model, and iii) optimizing the use of these resources under possible “policy/environmental” targets in the view of minimizing environmental impacts (e.g. global warming) or maximizing the penetration of renewable energy. The solution minimizing impacts from GHG emissions highlighted that domestic agricultural field-residues (e.g. straw/stover), along with the biomass fraction of municipal solid waste, chicken manure, and woody biomass, were optimally used for combustion-CHP (combined heat and power) or heat-only, as to phase-out coal- and oil-fired power and district heating plants. Cow and pig manure should undergo liquid/solid separation for further combustion-CHP of the solid and use on-land of the liquid, or be digested for biogas-CHP production, for the same reason. Subsequent upgrading of biogas to biomethane for use in vehicles was chosen only if a renewable target (as prescribed by the European Union’s Renewable Energy Directive RED) was imposed as a system-constraint, but it did not represent the most beneficial use from a GHG minimization perspective. Residues/by-products from food-industry with high nutritional value (e.g. whey, brewer’s grain, sugar beet residues, potato pulp, and soymeal) should be diverted to the feed sector, as feeding was found to be the optimal solution from a GHG minimization perspective. When allowing the system for producing energy crops, only cultivation of willow and *Miscanthus*, with further conversion in combustion plant for CHP and heat-only production, was highlighted to be beneficial from a GHG minimization perspective. This, however, was not the case for other environmental objectives, e.g. water footprint due to the induced effect on land, i.e. indirect Land-Use Change (iLUC). In this respect, cultivation of energy crops in Denmark increased feed import thus increasing water depletion-related impacts elsewhere. A similar trade-off was observed when minimizing impacts on N-eutrophication: with respect to this, cultivation of energy crops should be avoided along with biogas production, as this implied additional N load to soil through fertilizers and digestate application on-land, respectively. Allowing import of biomass/biofuels resulted in increased import of wood chips and pellets for direct combustion when minimizing impacts from GHG emissions. A multi-objective solution, aiming at finding an optimal solution across a number of environmental impact categories, was also established based on fuzzy intervals. Such a solution highlighted that improvements compared to the baseline 2013 are possible in all environmental compartments simultaneously. It was found that the GHG emissions could be decreased by 20% compared with the 2013 level without compromising other environmental compartments.

Herzog, T., 2009. World Greenhouse Gas Emissions in 2005. WRI Working Paper. World Resources Institute, Washington DC, Unites States. Available online at: <http://www.wri.org/publication/navigating-numbers> (accessed December 2015).